Construction-related Nosocomial Infections for Hospitalized Patients: Decreasing the Risk of Aspergillus, Legionella and Other Infections

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Decreasing the Risk of Construction-related Nosocomial Infections for Hospitalized Patients

Introduction and Rationale

Given the current restructuring in the Canadian health care system, several health care facilities are, or will be, undergoing construction or renovations to adapt to the changes. Potential health risks for patients, staff, and visitors may consequently develop if dust particles contaminated with bacteria and fungi are dispersed[1] and are not appropriately contained. The absence of early planning that integrates infection control, engineering services and building design in construction or renovation projects may lead to increased nosocomial (hospital-acquired) infections, a rise in allergen load, and workplace hazards[2]. Several reports have documented specific incidents of construction-related nosocomial infections caused by either *Aspergillus*[3-27] or *Legionella* species[28-32]. The mortality rate is high for both nosocomial aspergillosis (65-100%)[24, 33-36] and legionnaires' disease (as high as 80%) in the immunosuppressed population if these infections are unrecognized and untreated[37, 38]. Clearly, hospital construction or renovation projects can pose a threat to patients and, less commonly, may be a health risk to staff and visitors.

Particular emphasis must be placed on prevention and surveillance to improve detection as nosocomial aspergillosis is difficult to diagnose and treat[39]. It is imperative that appropriate infection control and preventive measures are employed throughout hospital construction or renovation projects to reduce the health risks associated with these activities[13, 16]. A multidisciplinary team of architects, engineers, infection control personnel, and representatives from environmental services, hospital administration, medicine and nursing[1, 2, 13, 16, 25, 39-43] is essential in planning activities for new construction projects and outlining infection control preventive measures[19, 25, 44]. Clear lines of communication among all personnel involved must be established in the planning phase of the project, and guidelines should be developed and followed to ensure that the communication plan is followed throughout the project[40, 45, 46].

The protection of susceptible patients and residents will depend on the acceptance and effectiveness of implementing infection control preventive measures. This will require a high level of commitment, understanding and co-operation from all personnel involved in the construction or renovation project (G. Granek, P. Eng., Toronto: personal communication, 1998).

Currently, no Canadian guidelines exist that address construction-related nosocomial infections and the preventive measures that are necessary to protect patients, health care facility staff, and visitors at the time of construction or renovation. The purpose of this paper is to provide a summary on construction-related nosocomial infections documented in the literature and to identify and delineate the measures that are necessary to prevent disease transmission. The focus of this paper is directed towards architects, engineers, infection control personnel and administrators who are involved in any aspects of health care facility construction or renovation. For this paper, construction or renovation activities refer to major and minor building activities that occur in established health care facilities and not new health care facilities that are being built.

A. *Summary of Construction-related Nosocomial Infections*

To assist the reader in understanding the risks and the importance of initiating infection control measures before hospital construction or renovation projects are started, a brief review of the literature on nosocomial infections related to these activities is provided. A review of the literature spanning a 20-year period (1978-1998) revealed many construction-related nosocomial outbreaks that occurred mainly in acute care facilities. As noted in Table 1, the majority of those identified were related to construction or renovation projects within or adjacent to the health care facility[3-5, 7, 8, 11-15, 17-22, 24, 25, 27, 28, 30-32, 47, 48] while others were associated with malfunctioning or improperly maintained ventilation systems when the health care facility was undergoing construction or renovation[9-11, 16, 26, 49, 50]. Furthermore, two documented outbreaks of pseudofungemia[51, 52] and one outbreak of pseudobacteremia[43] occurred when dust particles

from construction or renovation projects contaminated laboratory specimens[51], bronchoscopy material[52], and blood culture bottles[43].

Table 1. Summary of the Documented Reports on Construction-related Nosocomial Outbreaks

Etiologic Agent	Underlying Medical Condition of Patients	Number of Patients Infected/ Colonized	Number of Patients who Died	Source of the Etiologic Agent	Reference/Year
A. flavus (3) *A. fumigatus* (2) *A. niger* (1)	Leukemia (6)	6	2 (related to underlying illness)	Repair of false ceiling due to a water leak in a store room housing intravenous (IV) supplies. Adhesive tape and arm boards were contaminated.	Grossman et al., 1985[25]
A. fumigatus *A. niger* *A. terreus*	Burn (2) Trauma (1) Perforated viscus and wound dehiscence (1)	4	Not available	Renovations in the inventory control department resulted in *Aspergillus* spores being dispersed and settled on the supply boxes. The packages inside became contaminated when the box was opened. Patients then became infected when the packages were opened during dressing changes.	Bryce et al., 1996[27]
A. fumigatus (18)	Leukemia (15) Myeloma (1) Lymphoma (1) Paramyelosis secondary to breast cancer	22	18	Spores were dispersed during demolition of ducts and false ceilings, removal of fibrous thermal insulating material (glass fiber), & work on roller-blind casings.	Perraud et al., 1987[24]
A. fumigatus (3)	Heart transplant (3)	3	2	Connecting bridge between the old and new unit allowed dust to circulate from a nearby construction project. In addition, one air vent was not properly closed.	Hospital Infection Control, 1990[53]

Etiologic Agent	Underlying Medical Condition of Patients	Number of Patients Infected/ Colonized	Number of Patients who Died	Source of the Etiologic Agent	Reference/Year
A. flavus (32)	Old cavitary tuberculosis (TB) Diabetes Idiopathic thrombocytopenic purpura (ITP) Leukemia Lung cancer Chronic obstructive pulmonary disease (COPD) Bacterial pneumonia	32	1	Construction activity adjacent to the hospital and a defective ventilation system in old wing of hospital (e.g., prefilters heavily soiled, gaps between the individual filters and framework). Unfiltered air was allowed to enter patient care areas.	Sarubbi et al., 1982[11]
A. terreus (4)	Bone marrow transplant (BMT) (2) Acute myelogenous leukemia (AML) (1) Disseminated choriocarcinoma (1) Diagnosis not provided in the remaining 2 patients	6	4	Renovations were taking place two floors below the intensive care unit (ICU). Air pressure in ICU was negative to hallway and nearby elevator shafts. This was thought to have occurred when a wall was built during earlier renovations. In addition, patient room ventilation was conventional rather than unidirectional.	Flynn et al., 1993[10]
A. fumigatus *A. flavus*	Hematologic malignancy (2) Advanced age (1) Renal transplant (7)	10 (retro-spective review of autospy reports)	10 (4 due to invasive aspergillosis)	Window air conditioners in the renal transplant unit heavily contaminated with *Aspergillus* spp. Unit was in close proximity to adjacent road construction.	Lentino et al., 1982[9]

Etiologic Agent	Underlying Medical Condition of Patients	Number of Patients Infected/ Colonized	Number of Patients who Died	Source of the Etiologic Agent	Reference/Year
A.niger *A.flavus* *A.fumigatus*	Diagnosis not provided (hospital admits patients with leukemia, lymphoma, myeloma, brain tumors, sarcomas, and metastatic carcinomas)	8	3	Believed *Aspergillus* spores settled on wet fireproofing material when it was installed during construction. Spores were dispersed when the dry fireproofing material was disturbed above false ceilings during renovation or maintenance.	Aisner et al., 1976[18]
A. flavus (5) *A. fumigatus* (6)	Patients on a Bone marrow transplantation/leukemic unit	13	5	Fire in an old building close to the hospital and repeated window opening by a patient shortly afterwards suggest fungal spores dispersed during the fire were the source. The hall carpet then became contaminated and was an ongoing source of the infection.	Gerson et al., 1994[3]
Aspergillus	Patients on burn unit, dialysis unit and oncology	5	not available	Air intake vents had not been covered during demolition on the nursing units where the patients were housed.	American Health Care Consultants, 1995[26]
Airborne fungi (3) *Candida tropicalis* (2) *Fusarium* (1)	BMT	7	6	Several potential sources included: loose wallpaper in corridor; poorly sealed chase openings and direct opening from BMT rooms with floors above and below; inadequate air exchange & exhausts; negative pressure in 4 of the 16 BMT rooms; high-efficiency particulate-air (HEPA) filters had not been maintained or changed in 4 years.	American Health Care Consultants, 1995[50]
A. fumigatus (3)	Oncology	3	1 (had BMT)	Remodelling of adjacent radiology department. Dust barriers had not been installed.	Berg, 1995[7]
Aspergillus	Patients on a hematology unit	5	5	Large scale excavation work while hospital was being rebuilt. The isolation rooms that housed the patients overlooked the building site.	Shields et al., 1990[22]

Etiologic Agent	Underlying Medical Condition of Patients	Number of Patients Infected/ Colonized	Number of Patients who Died	Source of the Etiologic Agent	Reference/Year
A. fumigatus (6)	Patients in intensive therapy unit for respiratory failure, Crohn's disease, chronic bronchitis, emphysema, asthma, multiple trauma, septic shock, abdominal aneurysm	6	3 (related to underlying disease)	Suggested spores in fibrous insulation material above perforated metal ceilings were dispersed during minor building in adjacent offices and stores areas.	Humphreys et al., 1991[14]
A. fumigatus (6)	BMT	6	6	Heavy fungal spore contamination resulted from construction of an adjacent BMT unit.	Barnes & Rogers, 1989[12]
A. fumigatus (3)	Renal transplant	3	1	Renovation activity on the floor above caused dust to be dispersed from false ceilings in the renal transplant ward.	Arnow et al., 1978[5]
Zygomycetes *Aspergillus* *Rhizopus indicus*	Premature infant with respiratory distress syndrome Premature infant with ligation of a patent ductus arteriosus	2	2	Major source of mould was dust above the false ceiling.	Krasinski et al., 1985[21]
Aspergillus	Immunosuppressive treatment for vasculitis	3	3	Construction work and demolition of hospital buildings adjacent to the medical unit the patients were on. Contributing factors: no special ventilation system and windows could not be completely closed.	Dewhurst et al., 1990[20]

Etiologic Agent	Underlying Medical Condition of Patients	Number of Patients Infected/ Colonized	Number of Patients who Died	Source of the Etiologic Agent	Reference/Year
A. flavus (6) *A. fumigatus* (1) *M. rhizopus* (1)	AML (3) Acute lymphoblastic leukemia (ALL) (3) Aplastic anemia (1) Metastatic Wilm's Tumour (1)	8	5	Directly related to increased spore counts from soil excavation that occurred during hospital construction in a preexisting facility.	Lueg et al., 1996[17]
A. fumigatus (3)	Renal disease - chronic renal failure (2) - Wegener granulomatosis	3	2	The outbreak coincided with hospital renovation on a unit near the renal unit on which the patients were being housed.	Sessa et al., 1996[15]
Aspergillus (3) *Zygomycetes* (2)	Burkitts's lymphoma (1) AML (1) ALL (3)	5	5	Exposure to construction activity was independently associated. Extensive renovation was taking place as well as new construction. Windows could be opened on the unit the children were on and the "reversible pressure" system did not provide the indicated pressure relationships.	Weems et al., 1987[16]
Aspergillus	AML (25) ALL (7) Chronic lymphocytic leukemia (CLL) (1) Chronic myelogenous leukemia (CML) (1) BMT (2)	36 (over 69 months)	17	Not provided, however, four cases were identified prior to hospital construction compared with 28 cases during construction and four cases after control measures were initiated, suggesting hospital construction was related to the outbreak.	Loo et al., 1996[13]
A. fumigatus (2) *A.flavus* (1) Unknown (2)	Neutopenic as a result of high-dose chemotherapy	5	not provided	There was a significant increase of mould in the air in the patient rooms and corridors after construction was started. Sealing windows and other areas suspected of causing leaks decreased amount of mould in the air. Therefore, leaks around windows were suspected to be major source.	Iwen et al., 1994[8]

Etiologic Agent	Underlying Medical Condition of Patients	Number of Patients Infected/ Colonized	Number of Patients who Died	Source of the Etiologic Agent	Reference/Year
A. flavus (4) *A. fumigatus* (1) *A. niger* (1) other *Aspergillus* spp.	Immunosuppression from -lymphoreticular malignancy (7) -high-dose corticosteroid therapy (3) -disseminated carcinoma (1)	11	11	Not provided. Patients were either located on the same floor as or one floor below the construction area.	Opal et al., 1986[4]
Scedosporium prolificans (inflatum) (4)	AML (3) ALL (1)	4	4	Source is unknown. The patients were housed in two isolation rooms at the entry of the unit, which was opposite to the construction zone.	Alvarez et al., 1995[48]
Not reported (CDC found serologic evidence of legionnaires' disease)	Psychiatric illnesses	81	14	Source was suspected to have been derived from soil excavation on hospital grounds of a preexisting facility.	Thacker et al., 1978[31]
Legionella pneumophila	One patient had myelodysplasia and neutropenia admitted for dental extraction. The other admitted for gastrointestinal bleed.	2	2	A water valve in the potable water supply was turned off near the area of soil excavation. Authors believe repressurization of the water supply after the valve was reopened may have caused massive descalment inside the pipe and led to the outbreak.	Mermel et al., 1995[32]
Legionella bozemanii (4)	Lymphoma (2) Uremia (1) Rheumatoid arthritis (1) Immune thrombocytopenic purpura	5	0	Soil entered water supply during construction and installation of new plumbing.	Parry et al., 1985[30]

Etiologic Agent	Underlying Medical Condition of Patients	Number of Patients Infected/ Colonized	Number of Patients who Died	Source of the Etiologic Agent	Reference/Year
Legionnaires' bacterium	20 of the patients were immunocompromised	49 (3 employees)	15	Aerosols from soil excavation or water-cooling towers were considered to be the source.	Haley et al., 1979[28]
Nocardia asteroides (7)	Chronic liver disease (4) Liver transplant (3)	7	6	Considerable amounts of dust were visible on ward surfaces and equipment. Renovations were being done on the unit at the time. Environmental screening was negative for *Nocardia* spp.	Sahathevan et al., 1991[47]
*Sporothrix cyanescens**	Pneumonia with abnormal chest x-rays that required bronchoscopy with biopsy (4)	4	0	Dust from renovation activity within and adjacent to bronchoscopy unit contaminated bronchoscopy material.	Jackson et al., 1990[52]
*Aspergillus Penicillium**	Diabetes, hyaline membrane disease, asthma, meconium aspiration, cerebral palsy, Wilm's tumour, ALL, bronchiolitis	13	0	Agar plates were left open to air and were not processed under laminar hood. Spores entered lab via false ceiling that was connected to renovation area. In addition, air was drawn in because of the negative pressure within lab.	Hruszkewycz et al., 1992[51]

Note. * These examples represent cases of pseudoinfection.

1. *Etiologic Agents*

Construction-related nosocomial infections primarily originate from fungi and, to a lesser extent, bacteria (see Table 1). The predominant fungus associated with these infections is *Aspergillus*. In particular, *Aspergillus fumigatus*[3-5, 7-9, 13-15, 17, 23-25, 27, 49, 54, 55], *A. flavus*[3, 4, 8, 9, 11, 13, 17, 25], *A. niger*[3, 4, 8, 9, 11, 13, 17, 27], and *A. terreus*[10, 27] have been reported in several outbreaks of nosocomial aspergillosis. Other fungi implicated include *Candida tropicalis*[50], *Candida parapsilosis*[21], *Fusarium*[50], *Zygomycetes*[16, 21], *Rhizopus indicus*[21], *M. rhizopus*[17], and *Scedosporium prolificans*[48]. The predominant bacterium was *Legionella*[28, 30-32], and the following species were identified: *L. pneumophila*[32] and *L. bozemanii*[30]. *Nocardia asteroides*[47] is another bacteria reported to have caused outbreaks. There were also two reported cases of psuedofungemia caused by *Sporothrix cyanescens*[52] and *Penicillium*[51], and one case of psuedobacteremia caused *Bacillus* spp.[43]. Since *Aspergillus* and *Legionella* species were the most frequently reported fungi or bacteria to have caused a construction-related nosocomial infection, a brief description of them is provided. By understanding the relationship between these organisms and construction or renovation activities, the reader will better understand the need for preventive measures.

Aspergillus organisms are ubiquitous fungi found in soil, water, and decaying vegetation[36, 56]. The fungal spores (conidia) proliferate on non-viable organic debris[57] and can remain viable for months in dry locations[58]. During construction or renovation activities, spores can be dispersed on dust or dirt particles[1] when floors, walls or ceilings are penetrated. Since *Aspergillus* spores are small (2.5-3.5μ) and they settle very slowly (0.03 cm per second), they can remain suspended in the air for prolonged periods of time[58]. This increases the possibility that they may be inhaled or contaminate environmental surfaces.

Normally, *Aspergillus* species are transient colonizers of man[59]. The small size of the conidia allows the organisms to reach the pulmonary alveolar spaces[59]. There are three main processes that can occur if *Aspergilli* species reach the lungs: colonization, hypersensitivity or invasion[60]. The host's

response is critical to the development of disease[60]. For instance, healthy individuals, such as health care workers, may become sensitized to *Aspergillus* but have only a minute risk of infection if exposed[61], whereas exposure to *Aspergillus* can be life-threatening and often fatal for patients who are immunosuppressed[33, 56, 62]. A clinical diagnosis of invasive pulmonary aspergillosis is difficult because early signs are nonspecific and the rate of isolation of the organism in sputum cultures is low[63]. Therefore, it is essential that preventive measures be initiated to decrease patients' or residents' exposure to dust particles contaminated with aspergillus spores, especially patients who are immunosuppressed.

Legionella is also a ubiquitous organism[37]. This gram-negative bacterium is found in natural aquatic environments[37] as well as soil and dust[64]. In hospitals, particular reservoirs included cooling towers, evaporative condensers, locally produced distilled water, heated potable water systems, and heating and air-conditioning systems[37, 56, 65, 66]. During construction or renovation projects, hospital water systems may be disrupted, and the hospital's potable water can become contaminated with *Legionella* when the water supply is restored[1]. This may be related to massive descalement in the water pipes as they are repressurized[32] or to the introduction of contaminated soil in the plumbing system[30]. *Legionella* can then proliferate in the hospital water supply if certain conditions exist, such as sediment in hot water tanks[67], low hot water temperatures at faucets[66], and water systems that are prone to stagnation[65, 66, 68, 69]. In addition, soil and dust containing dormant forms of *Legionella* can become airborne during soil excavation, which subsequently can contaminate cooling towers[64] or be inhaled by susceptible patients[28, 30, 31].

The incidence of a nosocomial infection caused by *Legionella* depends on the resistance of the host, exposure of the host to a contaminated source, and the degree of contamination[38, 70, 71]. Legionnaires' disease is thought to be acquired by inhalation of aerosols contaminated with *Legionella* from the hospital's water supply[38, 71-73]. Legionnaire's disease can be difficult to diagnose[68, 72] because specialized laboratory methods and culture media are required[70]. Thus, preventive measures to decrease the transmission of *Legionella* should be implemented when hospital construction or renovation activities that

disrupt some of the health care facility's water supply are planned.

2. *Source of the Microorganism Causing Infection in Construction Settings*

The source of construction-related microorganisms causing nosocomial infections can be categorized as biological or mechanical. Biological sources include mould, dust, or soil contaminated with fungal spores or bacteria. Contaminated mould or dust particles have been reported to come from above the false ceilings[5, 21, 24, 25, 51], from fibrous insulating material[14, 24], roller-blind casings[24], and fireproofing material[18]. In addition, an outbreak of aspergillosis occurred after a fire demolished an old building adjacent to a hospital's bone marrow transplantation unit[3]. Gerson and colleagues believed that fungal spores dispersed during the fire entered the hospital through an open window and contaminated the hall carpet. Other outbreaks have been reported when contaminated dust particles infiltrated adjacent patient care areas when no impermeable barrier was erected[7] or windows were not properly sealed[8, 16]. In an additional report, cutaneous aspergillosis developed in four patients when dressing supplies were used that had been contaminated during construction activities in a central inventory area[27]. Last, soil excavation was suspected of dispersing fungal spores[9, 17, 22] or bacteria[28, 30, 31] into the air, which was then subsequently inhaled by susceptible patients.

Mechanical sources of outbreaks have been related to the hospital's plumbing or ventilation system. Leaking water pipes have been reported to cause water damage to the false ceiling in an intravenous (IV) supply storeroom[25]. During renovations to repair the ceiling, dust and mould particles were dispersed and contaminated the IV supplies. The contaminated supplies were used on children with leukemia, in six of whom cutaneous aspergillosis developed[25]. An outbreak of legionellosis was reported following the installation of new water pipes[30]. Potentially, soil contaminated with *Legionella* entered the water supply at the time the new pipes were connected to the existing hospital plumbing system[30]. In another example, legionnaires' disease occurred after the repressurization of the water supply when a valve

near the area of soil excavation was reopened after being closed[32]. The sudden surge of water was thought to have caused a massive descalment inside the water pipes, which led to the outbreak[32].

A construction-related nosocomial outbreak of *A. flavus* occurred when a defective ventilation system allowed unfiltered air from an adjacent construction zone to circulate into patient care areas. Prefilters were heavily soiled and gaps were found between the individual filters and framework[11]. Hospital ventilation systems have been implicated in the development of nosocomial fungal outbreaks during periods of construction or renovation when 1) vents were not closed properly[26, 49]; 2) incorrect air pressurization in patient care areas allowed airflow to move from dirty areas to clean areas[10, 16, 50]; 3) air exchange and exhaust were inadequate[50]; or 4) HEPA filters were not properly maintained[50]. Finally, an outbreak of aspergillosis was related to a heavily contaminated window-mounted air conditioner that was adjacent to a road construction project[9].

As the review of the literature suggests, a variety of biological and mechanical sources exist in health care facilities during construction or renovation activities. It would be prudent for health care personnel and other professionals involved in construction or renovation activities to consider potential sources of high concentrations of microorganisms, which may cause nosocomial infections, when planning such projects in health care facilities.

3. *Patients Who are at Risk and the Associated Risk Factors*

Certain patients are at increased risk of construction-related nosocomial infections. Any hospitalized patients who are exposed to construction activities or soil excavation may have an increased risk of acquiring a construction-related nosocomial infection. Weber and colleagues found that hospitalization during construction was an independent risk factor for development of invasive nosocomial fungal infection ($p = 0.09$)[23]. Similarly, Weems and associates demonstrated that the incidence of invasive aspergillosis or invasive zygomycosis was significantly higher during construction periods ($p = 0.001$

Fisher's Exact Test)[16]. Klimowski and colleagues reported an increased incidence of aspergillosis over 20 years that coincided with the increasing number of internal hospital renovation projects, and to a lesser extent, external construction projects[19]. Soil excavation and construction have also been identified as risk factors in an outbreak of *L. bozemanii*[30]. Last, Thacker and associates showed a relationship between patients who were allowed access to the hospital grounds at the time of soil excavation and risk of acquiring legionnaires' disease ($p < 0.0001$)[31]. Thus, the importance of decreasing patients' exposure to construction activities or soil excavation is evident.

In addition, the patient's underlying medical condition is important in determining who may be at risk of a construction-related nosocomial infection. The underlying medical condition is one of the best predictors for those who may develop invasive aspergillosis[74] or legionnaires' disease[56]. A brief description of the immune response to fungal and bacterial organisms is provided to help the reader understand the relationship between the underlying medical condition and development of infection. When a healthy immune system is exposed to *Aspergillus*, macrophages kill the conidia while neutrophils are a defense against the mycelia. However, when the host is immunocompromised, an increased likelihood of invasion of tissue by *Aspergillus* can occur[15]. Previous research has found that the duration of granulocytopenia was an independent risk factor for invasive nosocomial fungal infections ($p < 0.01$)[23]. In contrast to the primary defense against *Aspergillus*, neutrophils play a less important role in the primary defense against *Legionella* that reach the lungs. Consequently, neutropenic patients are not at excessive risk for legionnaires' disease[69].

The following immunosuppressive conditions have been frequently reported as risk factors for construction-related nosocomial fungal infections: graft versus host disease requiring treatment[56, 74-76]; prolonged neutropenia or granulocytopenia because of cytotoxic chemotherapy[3, 15, 17, 23, 48, 74, 75, 77, 78]; prolonged use of antibiotics to treat fevers or previous infections[15, 17, 48, 74, 75]; and steroid therapy[74, 76]. Other risk factors reported to influence the development of aspergillosis include dialysis and mechanical

ventilation[79], smoking[74] and the age of the patient[75], the very young and very old being at greater risk[21, 74]. Grauhan and colleagues reported that the risk of a fungal infection increases in patients who exhibit three or more of the risk factors ($p < 0.001$)[79].

Similarly, prolonged granulocytopenia because of cytotoxic chemotherapy[30, 38, 42, 65, 69, 72, 73, 80, 81], steroid therapy[38, 42, 65, 69, 72, 73, 80, 81] and advanced age have been reported to be risk factors for acquiring and dying from legionnaires' disease[56]. It is also possible that males may be at greater risk[31, 65, 72, 73, 80, 81] since more men than women are reported to have acquired legionnaires' disease. Additional risk factors for legionnaires' disease include smoking[65, 72, 73, 80, 81], excessive use of alcohol[65, 72], surgery[73], diabetes[72, 81], and neoplastic, pulmonary, renal or cardiac disease[38, 69, 72, 80, 81].

In summary, patients who have any of the risk factors listed in Table 2 may be at greater risk during construction or renovation activities. Patients who are immunosuppressed are noted to be at greatest risk of acquiring a nosocomial fungal infection or Legionellosis[3, 7, 15, 30, 48, 69, 72, 76, 81]. Examples include patients who have undergone bone marrow or solid organ transplant, other oncology patients who are receiving chemotherapy, patients receiving dialysis, and patients taking immunosuppressive medication.

Table 2. Risk Factors for Developing Construction-related Nosocomial Infections

Risk Factors for Infections with Filamentous Fungi	Risk Factors for Legionnaires' Disease
1. Exposure to construction activities	1. Exposure to soil excavation during construction and malfunction of plumbing systems
2. Immunosuppressive conditions (e.g., bone marrow or solid organ transplantation; graft versus host disease requiring treatment; prolonged neutropenia or granulocytopenia because of cytotoxic chemotherapy; prolonged use of antibiotics to treat fevers or previous infections; and steroid therapy or other immunosuppressive therapy)	2. Immunosuppressive conditions (e.g., bone marrow or organ transplantation; graft versus host disease requiring treatment; prolonged granulocytopenia because of cytotoxic chemotherapy; and steroid therapy)
3. AIDS, congenital immunodeficiencies	3. Advanced age
4. Dialysis, renal failure	4. Chronic pulmonary disease
5. Diabetic ketoacidosis	5. Smoking
6. Mechanical ventilation	6. Excessive use of alcohol
7. Smoking	7. Surgery
8. Age of the patient (e.g., neonates and very old have a greater risk)	8. Diabetes
	9. Neoplastic disease
	10. Renal failure
	11. Cardiac failure

B. *Risk Assessment and Infection Control Preventive Measures*

A proactive approach is required to decrease the occurrence of construction-related nosocomial infections. Previous authors have reported that the key to eliminating *Aspergillus* infections is, first, to minimize the dust generated during the construction activity and, second, to prevent dust infiltration into adjacent patient care areas[45]. These activities will also eliminate other dust-borne fungi (e.g., *Rhizopus*) capable of causing invasive fungal infections. Likewise, special attention should be directed to the hospital's plumbing system when disruptions occur during construction or renovation projects. Attention

to infection prevention measures and ensuring appropriate personnel are involved is necessary to protect susceptible patients.

To meet these objectives, preventive measures should be clearly outlined[13, 16] in the contract documents, before any construction or renovation project is started, and every effort made to ensure that they are maintained for the duration of the project. A multidisciplinary team is also needed to ensure that the preventive measures are effective[19, 44, 82]. Similarly, administrative support is of foremost importance for the safe completion of the project. The responsibilities of all personnel involved in the project needs to be clearly outlined in the contract documents. This will help to identify the liability of all personnel involved. The following section of this paper deals with identifying the preventive measures needed to decrease the risk of construction-related nosocomial infections and discusses strategies to improve the communication of infection control personnel with other professionals.

1. *Risk Assessment and Preventive Measures Checklist*

The Risk Assessment and Preventive Measures Checklist (see Appendix A) is recommended to assist the multidisciplinary team during the design process to identify the patient population at risk and the preventive measures that should be initiated. This tool was adapted from the Infection Control Construction Permit developed by V. Kennedy, formerly from St. Luke's Episcopal Hospital, Houston, Texas (oral permission was obtained). The original tool has been modified for use in other health care facilities. The tool describes four levels of construction activities that may occur within a health care facility. In addition, the tool lists four risk groups, ranging from lowest to highest risk. The project planning committee can use the tool to decide risk groups that may be affected because of proximity to or exposure to the construction zone. With the use of the Construction Activity/Infection Control Matrix, appropriate infection prevention measures are identified by matching the construction activity with the risk group[83].

The Risk Assessment and Preventive Measures Checklist was adapted from the original source by listing the preventive measures under two categories: construction/renovation activities and plumbing activities. The preventive measures were then further subdivided into categories that represent the personnel responsible for the project (e.g., engineering/maintenance staff). Additional preventive measures suggested in the literature were included. Furthermore, the section on construction activity was expanded to include more examples. Lastly, some modifications were made to the Infection Control Risk Group. It was renamed the Population and Geographical Risk Group, and some changes were made to the four categories based on suggestions from the literature. The incidence of construction-related nosocomial infections should decrease by the early identification of the population risk group and the appropriate preventive measures that need to be initiated.

2. *Preventive Measures*

Studies have demonstrated the effectiveness of preventive measures when implemented in health care facilities[4, 13, 33, 84] as well as in commercial and residential buildings[85] that were undergoing renovations. In three of these studies[33, 84, 85], the preventive measures were initiated before the renovations were started. After implementing the measures, Overberger and colleagues collected air samples from various locations both within and outside the construction zone before, during, and after the construction (30 weeks)[33]. In the construction zone, total particulate concentrations and spore counts rose steadily and then declined at the end of the construction, whereas in adjacent patient care areas total particulate concentrations and spore counts did not change significantly from baseline levels. The preventive measures were effective in protecting the patients from being exposed to high levels of airborne particulates and fungal spores generated during construction activities[33]. In a similar study, Streifel and colleagues demonstrated that preventive measures reduced infiltration of fungal spores when a building adjacent to the hospital was demolished[84]. Concentrations of airborne microorganisms decreased during the testing of

three commonly used methods to minimize dust and prevent migration of dust particles into adjacent areas[85]. The three methods tested were:

1) use of a plastic barrier from the floor to the ceiling to isolate the construction zone plus negative pressurization;

2) use of a plastic barrier and a high-efficiency exhaust fan with a HEPA filter; and

3) use of a plastic barrier and a portable exhaust fan with a side-draft hood.

The results of the study indicated that the second method was the most effective in reducing concentrations of airborne microorganisms in the construction zone and preventing migration of dust particles to adjacent office areas[85]. It should be noted that the airflow rates and whether the plastic barriers were erected to the true ceiling or false ceiling were not reported in the study.

For the two remaining studies, the preventive measures were initiated after the outbreak of a nosocomial fungal infection[4, 13]. Before implementation of the preventive measures, the incidence density for nosocomial aspergillosis during construction was 9.88 per 1,000 days at risk compared with baseline levels, which were 3.18 per 1,000 days at risk[13]. However, after the control measures had been implemented, the incidence density decreased to 2.91 per 1,000 days at risk during construction[13]. Similarly, Opal and associates reported that there were no additional cases of disseminated aspergillosis after infection prevention measures were started compared with 11 cases that occurred before the measures were implemented[4].

The results of these studies indicate that preventive measures are effective in decreasing the incidence of construction-related fungal infections. In addition, the results suggest that preventive measures are cost-effective since the patients' safety was maintained and further cases were prevented.

The information available on the effectiveness of preventive measures for *Legionella* during construction or renovation projects consists of expert opinions and not controlled studies. In one reported outbreak, control was achieved by superheating and hyperchlorinating the hospital's hot water system, thus

preventing further cases of nosocomial pneumonia caused by *Legionella bozemanii*. It was believed that *L. bozemanii* entered the hospital's water supply during the installation of new plumbing at the construction site[30]. In a similar report, Mermel and colleagues suggested the following preventive measures should be taken during periods of excavation on hospital grounds or when the plumbing system has been shut down and is later repressurized:

1) hyperchlorination of stagnant potable water should be carried out before repressurization;

2) persistent discoloured water should be reported to maintenance and infection control personnel;

3) the water supply in areas housing patients who are immunocompromised should be cultured for *Legionella*; and

4) heightened surveillance may be warranted[32].

Additional preventive measures identified in the literature include selecting plumbing materials that do not promote the growth of bacteria and are resistant to corrosion[37, 86, 87], removing faucet aerators and other obstructing and stagnating features such as long pipe lines and dead-ends[30, 37, 68, 87], assessing hot water temperature to ensure that it meets the standards set by the hospital[87], and ensuring that a regular program of preventive maintenance is in place and undertaken[30, 42, 68, 87].

These suggestions might have been beneficial in the following situation. There was a sudden increase in the number of cases of legionnaires' disease reported in a hospital after its emergency water pump failed. The water pressure dropped for only a few minutes, but the water remained discoloured for up to four weeks[29]. In an attempt to recreate the change in water colour, the water supply to one wing was turned off for five minutes and then turned back on. There was a 30-fold increase in the concentration of *Legionella pneumophila* in a second water sample taken after the water supply had been turned back on compared with a sample taken before the water supply was turned off[29].

Potential preventive measures as identified by the literature are listed in Table 3. The multidisciplinary planning committee should base their selection of the measures according to the activity

planned, its duration, and the patient population that may be affected by the construction or renovation project. Although the construction activity may be considered minor, infection control personnel should be notified when high risk populations are involved. For example, if the construction/renovation activity involves drilling holes in the walls in a bone marrow transplant unit, infection control personnel should be consulted to ensure appropriate preventive measures are in place as needed. The preventive measures are categorized according to phases: preconstruction, construction, and post construction.

Table 3. Infection Prevention Measures for Hospital Construction

Preconstruction Preventive Measures

1. The infection control personnel should be consulted to provide information on infection prevention measures[1, 41].

2. Identify patient population(s) that may be at risk and the prevention measures to ensure their safety[41].

3. Identify essential services (i.e., water supply, electricity, ventilation systems) that may be disrupted and measures to compensate for the disruption[41, 88].

4. Clearly outline the infection control personnel's authority to stop construction projects if breaches in prevention measures arise[26].

5. Review and assess the integrity of the health care facility's exterior structure, the spatial separations and its ventilation and water supply for any infection control problems[41] (G. Granek, P. Eng., Toronto: personal communication, 1998). For example, it is important to ensure that the air pressure, air flow, and air exchange rates have been assessed by the HVAC personnel and that filtration systems are working appropriately. Any infection control problems identified should be corrected prior to starting the construction activity[89].

6. Ensure that the plumbing materials selected are durable and resistant to corrosion and bacterial growth[37, 86, 87]. Items made of degreased stainless steel, natural unpigmented polypropylene, polytetrafluoroethylene (PTFE), or polyvinyldenefluoride (PVDF) are examples of materials that are nonleaching and will not degrade the quality of the water[87].

7. Educate and train all personnel involved in the construction or renovation activity on the infection prevention measures[1, 41, 87, 88]. For example, the infection control personnel could educate the project managers and contractors who then ensure that the construction workers receive the appropriate education.

8. Outline methods for dust containment and removal of construction debris[41].

9. Establish traffic patterns for construction workers that avoid patient care areas[1, 4, 21, 33, 41, 90].

10. If possible, designate an elevator to be used solely by the construction workers[1, 33]. If possible, ensure that the ventilation of the elevator cab and shaft is not recirculated in the hospital.

11. Seasonal effects related to infections should be considered in the work plan for projects (G. Granek, P. Eng., Toronto: personal communication, 1998).

12. Ensure that a regular program of preventive maintenance is in place for the hospital water and ventilation system[30, 42, 68, 87]. For example, Wallin recommends that every seven months is the optimal cleaning frequency for HVAC systems[91].

Construction Preventive Measures

1. Patients who are immunosuppressed should be moved to an area away from the construction zone if the air quality cannot be ensured during construction[13]. These patients should wear a mask if it is necessary to transport them through a construction area.

2. All windows, doors, air intake and exhaust vents should be sealed in areas of the hospital adjacent to buildings that are going to be demolished plus areas housing patients who are most susceptible[84], to prevent air leaks into patient care areas.

3. A dust barrier should be created from the floor to the true ceiling and edges sealed[1, 4, 21, 33, 88, 90]. Plastic sheeting or Sheetrock are examples of materials that could be used to create dust barriers for short-term and long-term projects respectively[1].

4. An impermeable dust barrier with an anteroom may need to be constructed if the project will take consecutive work shifts to complete[33].

5. All windows, doors, vents, plumbing penetrations, electrical outlets and any other sources of potential air leak should be sealed in the construction zone[8, 11, 33, 92].

6. Air pressure within the construction zone should be negative compared with adjacent areas[1, 33, 90]. A fan may be used for this purpose[21, 33].

7. Air in the construction zone should be exhausted directly outside. If this is not possible, then the air should be filtered through a HEPA filter before being recirculated in the hospital[93]. The integrity of the HEPA filter should be assessed to ensure that it is not punctured.

8. Open ends of exhaust vents should be capped to prevent air, exhausted from the construction zone, from being drawn back into patient care areas or released to outdoor streets around the hospital[33].

9. Air ducts and spaces above ceilings should be vacuumed before the construction project is started if it involves these areas[1, 21].

10. A moist carpet should be placed inside the anteroom and inside the entrance of the construction zone to trap dust. The carpet should be vacuumed daily[33] or when visibly soiled.

11. A mat with a sticky surface should be placed in the patient care area, directly outside the anteroom, to trap dust from the equipment and shoes of personnel leaving the construction zone[33]. The mat should be vacuumed daily or when visibly soiled.

12. Construction workers should wear protective clothing when working in the construction zone[1] because of the high concentration of dust. To limit dust dispersion, construction workers must remove the protective clothing and vacuum themselves with a HEPA filtered vacuum to remove dust from their clothing before leaving the construction zone[1] if there is no external nonpatient area exit. The supplier of the HEPA filtered vacuum should be negotiated in the contract documents.

13. Adjacent areas should be vacuumed daily or more frequently if needed with HEPA filtered vacuums[1].

Construction Preventive Measures

14. Clean or sterile supplies and equipment should not be transported through a construction zone to reduce the risk of contamination[1].

15. Used supplies and equipment should be enclosed in covered containers when being transported to prevent unnecessary contamination in other areas[1].

16. Consideration should be given to remove the debris by the construction workers in the evening when patients are in their rooms and visitors have left. If this is not possible, debris should be removed at the end of the work day by construction workers. Debris should be in covered containers or covered with moistened sheets before it is removed from the construction area[1, 33]. Exposure of patients to debris should be minimized as much as possible.

17. An external chute may be another option for removal of debris if construction is not taking place on ground level[1, 4].

18. Discoloured water should be reported promptly to maintenance and infection control personnel[32]. Alternate water sources should be considered for patient use.

19. Surveillance for *Legionella* disease in patients should be intensified during soil excavation on hospital grounds or when water supply has been disrupted and then repressurized[32].

20. Faucet aerators and other obstructing and stagnating features (e.g., long pipes and plumbing dead-ends) should be removed if possible[30, 37, 66, 87].

21. Copper-8-quinolinolate formulation may be considered for application to walls, doors, frames, baseboards, exterior surfaces of radiators, vents in the rooms in the construction area and above false ceilings in adjacent areas[4, 13].

22. Infection control personnel should regularly visit the construction site until the project is done to ensure that preventive measures are being adhered to or that appropriate modifications are made if there are any onsite design changes. If any concerns are identified, they should be brought to the attention of the program manager.

Post Construction Preventive Measures

1. Thoroughly clean the construction zone, including all horizontal surfaces, before the barrier is removed, and again after the barrier is removed and before patients are readmitted to the area[1, 5, 7, 21]. Allow time for all dust to settle before doing final cleaning.

2. Infection control personnel should check the area before patients are readmitted to the finished area.

3. Ensure that multidisciplinary project committee or designate conducts a final walk through to ensure ventilation system is functioning properly in construction zone and adjacent areas[16, 41].

4. Flush water lines prior to use if they were disrupted[1, 32].

5. If there are concerns about *Legionella*, consider hyperchlorinating stagnant potable water[32] or superheating and flushing all distal sites[30] before restoring or repressurizing the water system.

6. Disinfect unused cooling towers and water supply in unoccupied portions of buildings before they are put in use[37].

7. Assess hot water temperature to determine that it meets the standards set by the hospital[87].

8. Ensure that multidisciplinary project committee or designate evaluates the preventive measures and reviews their effectiveness for any problems and positive outcomes[41].

3. *Personnel Involved*

The need to understand the responsibilities of the personnel involved in the project and to establish and maintain clear lines of communication between them and infection control personnel is important in the prevention of construction-related nosocomial infections[40, 45, 46]. Information from infection control personnel during the planning stage can be a mainstay in the prevention of nosocomial infections. To decrease the incidence of construction-related nosocomial infections, it is crucial that infection control personnel are consulted and play a major role in planning construction or renovation projects.

Familiarity and involvement with the capital planning process will help infection control personnel to become equal partners in hospital construction or renovation projects. The ministries of health for most of the provinces and territories have developed a capital planning document that health care facilities must follow, depending on the total cost of the project, when they embark on construction or renovation projects. These ensure that 1) resources are used efficiently and effectively; 2) the approval process is streamlined; and 3) the key participants' roles and responsibilities are identified[94]. Although the

documents are different for each of the provinces and territories, the principles are generally the same. After doing a needs assessment, health care facilities submit a proposal to the Ministry of Health, outlining the need for the project and how it will fit into the general long-term plans of the facility and the region. If the proposal is accepted, schematic plans are developed and revised as the project advances. Approval of the final contract documents are sought from the Ministry of Health before bids from the documents are tendered. Construction begins after approval of the contract award has been approved by the province's or territory's Ministry of Health. Commissioning is the final phase. This involves ensuring that the construction or renovation activity was completed according to the plan and all systems are functioning properly[94-97].

Infection control personnel will be more successful in their efforts if they are aware of who the key players are and educate them regarding the need for preventive measures to decrease construction-related infections. There are three key roles involved in construction projects that the infection control personnel should be aware. The roles are 1) facility owners and their agents and employees; 2) design professionals; and 3) constructors, contractors, subcontractors, building trades and suppliers (D. Ardiel, Architect, London, ON: personal communication, 1998). There are additional personnel who have legal rather than contractual rights and responsibilities. These authorities who have jurisdiction include building, fire and zoning officials and provincial ministry officials. The following discussion briefly describes the responsibilities of some of the professionals involved in hospital construction and renovation projects and how collaboration with the infection control personnel can decrease the risk of construction-related nosocomial infections. The responsibilities of the authorities who have jurisdiction is beyond the scope of this paper and will not be discussed.

1. *Facility Owners, Their Agents and Employees*

a. *Administration*

Administrative support is essential for the successful completion of the construction project. Hospital administrators should ensure policies and procedures exists within the health care facility that clearly outline the responsibilities of those involved with the construction project and the infection control preventive measures that are needed. Infection control personnel could provide some education on infection control concerns and the importance of preventive measures to hospital administrators to assist in the development of the policies and procedures.

b. *Facility Project Managers*

The facility project manager is the representative of the health care facility undergoing the construction or renovation project[82]. The responsibilities of the facility project manager include overseeing and coordinating the activities of all personnel involved in the construction project and directing information among them (D. Ardiel, Architect, London, ON: personal communication, 1998). Facility project managers are also responsible for deciding who should be represented at the planning and design development meetings[82]. Consequently, facility project managers have a key role in hospital construction or renovation projects.

It is advantageous for infection control personnel to develop close working relationships with the facility project managers in their health care facility. Education could be provided to the facility project managers on infection control concerns and the importance of preventive measures in decreasing construction-related nosocomial infections. Infection control personnel should be involved during the planning and design development phase of the capital planning process. In addition, it should be established which infection control personnel have the authority to stop the construction project if there is a significant breach in the preventive measures. This should be incorporated into the contract documents

at the time the construction project is planned.

c. *Environmental Services*

Environmental service staff, either facility or contract, are responsible for keeping areas adjacent to the construction zone clean and clear of debris and for thoroughly cleaning the construction or renovation area before the patients are readmitted into these areas[1, 5, 7, 21]. It should be noted that in some circumstances, the contractor is responsible for cleaning adjacent areas. Therefore, before starting the construction project, a decision should be made as to who is responsible for cleaning adjacent areas, either the contractor or environmental services. Infection control personnel can collaborate with environmental service staff during the construction phase of the capital planning process by making recommendations on the appropriate cleaning procedures that they should be using in areas adjacent to the construction site.

d. *Medical and Nursing Staff*

Medical and nursing staff are responsible for maintaining the patients' safety during the construction or renovation project. They should be aware of patient populations at risk, potential hazards that construction/renovation activities pose to patients, and the preventive measures. Infection control personnel can collaborate with the medical and nursing staff to identify patients considered at risk of acquiring construction-related nosocomial infections[42], such as those who are immunosuppressed because of their underlying medical condition or medical treatment[3, 7, 15, 30, 48, 69, 72, 76, 81]. Examples of these patients include oncology patients undergoing cytotoxic chemotherapy, bone marrow and solid organ transplantation patients and dialysis patients. Increased awareness in the medical and nursing staff may enhance the initiation of timely investigations for patients suspected of having nosocomial pneumonia[42] and the identification of deficiencies in dust containment on the nursing units.

2. *Design Professionals*

Architects

The architect is responsible for ensuring that the construction or renovation building design meets the health care facility's building objectives. The architect must comply with professional standards and building and fire codes in the development and design of the construction or renovation project[98] (D. Ardiel, Architect, London, ON: personal communication, 1998). It is advisable for the infection control personnel to be aware of existing building codes and professional guidelines or standards that consider infection control issues[1]. A list of possible standards/codes that may help the infection control personnel is provided in Appendix B. By being knowledgeable of the codes and standards, infection control personnel can discuss the design of the project with the architect during the planning phase of the capital planning process. To ensure that preventive measures are incorporated into the construction project, infection control personnel could explain the reasons for and the importance of following preventive measures to the architect and other professionals involved with the construction[1, 92].

3. *Constructors, Contractors, Subcontractors, Building Trades and Suppliers Engineer, Maintenance Staff and Contractors*

It should be noted that maintenance staff may be the personnel who perform the work depending on the type of construction activity that is undertaken in health care facilities,. Likewise, engineers may be the personnel who design the project. Thus, their roles are discussed under this category along with contractors.

Engineers, maintenance staff, and contractors too, must follow building and fire codes and professional standards in completing construction projects. Their responsibilities include planning and carrying out construction or renovation projects and repairing structures, equipment and utilities within the health care facility[42, 88]. As well, their responsibilities include monitoring and evaluating the ventilation system within the construction zone and adjacent areas to ensure that it is functioning properly

not only before the project starts but also throughout its duration and at completion[88]. This involves an assessment of the airflow, air pressure, and air exchange rate. In addition, it includes assessing, cleaning, and evaluating the integrity of filters and ducts[88]. The engineers, maintenance staff and contractors are also responsible for creating the dust barrier and helping to prevent dust infiltration into adjacent areas during the construction project[88]. The contractors are also responsible for keeping the construction area clean and clear of debris. Furthermore, if the hospital's plumbing system is affected by the construction, they are responsible for monitoring its integrity, assessing for leaks or minimizing dead-end reservoirs[88]. Engineers and maintenance staff can help train contractors in safe construction practices while they are working in health care facilities[88].

Since these professionals conduct the construction activity, infection control personnel should be in communication with them during the construction phase of the capital planning process. Infection control personnel, in collaboration with the project managers, are responsible for ensuring infection prevention measures are initiated and followed for the duration of the project[1]. Thus, they can advise the engineers, maintenance staff and contractors on appropriate preventive measures for the activity that is under way. When the project is complete, infection control personnel should review and evaluate the effectiveness of the preventive measures with other members of the construction planning committee to identify positive outcomes and any problems that may have occurred[41].

Summary

Hospital construction or renovation projects can cause infection for some patient populations, in particular, the immunocompromised. Clearly, it is crucial that a proactive approach be taken to ensure that construction-related nosocomial infections are limited. This involves having a multidisciplinary team in place to plan and implement preventive measures throughout the duration of the construction project. Infection control personnel should be active team members in all phases of the construction or renovation

project. They play a major role by providing education to personnel and ensuring that preventive measures are identified, initiated and maintained. By ensuring that the appropriate preventive measures are in place and clear lines of communication exist among the personnel, patient safety will be enhanced.

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Appendix A: Risk Assessment and Preventive Measures Checklist for Hospital Construction and Renovation

Purpose

The Risk Assessment and Preventive Measures Checklist was developed to help members of the construction/renovation planning committee reduce the incidence of construction-related nosocomial infections. The checklist ensures that the patient populations at risk will be identified and the appropriate prevention measures will be initiated *before* a construction/renovation project is started. Through a structured approach, the onset of nosocomial infections will be limited.

Instructions on How to Complete

The Risk Assessment and Preventive Measures Checklist is to be completed *during the planning design phase* of the construction/renovation project by the multidisciplinary planning committee. Infection control personnel must be involved in each phase of the project to ensure that the appropriate prevention measures are initiated and followed. The type of "Construction Activity" is first identified by selecting the level of activity that best describes the project being planned for the health care facility. The types of construction activity are described in Part A. The second step (Part B) involves identifying the "Population and Geographical Risk Group" that may be affected by the project because of its physical proximity or exposure to the construction/renovation activity. There are four groups described in Part B that will help the planning committee to identify the risk group. The appropriate infection prevention measures are identified by matching the construction activity with the population risk group in Part C. As indicated by the shaded areas in the "Construction Activity and Risk Group Matrix", the checklist must be completed and a copy sent to the infection control personnel to be filed for all Class III and IV categories. Adaptations to the prevention measures can only be made after approval has been provided by the infection control personnel.

Risk Assessment and Preventive Measures Checklist for Hospital Construction and Renovation

Location of Construction:	Project Start Date:	Estimated Duration:
Project Manager (PM):	Contractor(s):	Infection Control Personnel (ICP):
PM's phone number:	Contractor's phone number:	ICP's phone number:

Yes	No	Construction Activity (see Part A)	Yes	No	Population Risk Group(see Part B)
		Type A: Inspection, non-invasive activities.			Group 1: Lowest Risk
		Type B: Small scale, short duration, minimal dust generating activities.			Group 2: Medium Risk
		Type C: Activities that generate moderate to high levels of dust, requires greater than one work shift to complete.			Group 3: Medium to High Risk
		Type D: Activities that generate high levels of dust, major demolition and construction activities requiring consecutive work shifts to complete.			Group 4: Highest Risk

Part A: Types of Construction Activity

Type A	Inspection and Non-invasive Activities: These include, but are not limited to, activities that require removal of ceiling tiles for visual inspection (limited to 1 tile per 50 square feet), painting (but not sanding), wall covering, electrical trim work, minor plumbing (disrupts water supply to a localized patient care area [e.g., 1 room] for less than 15 minutes), and other maintenance activities that *do not generate* dust *or* require cutting of walls *or* access to ceilings other than for visual inspection.
Type B	Small scale, short duration activities that create minimal dust. These include, but are not limited to, activities that require access to chase spaces, cutting of walls or ceilings where dust migration can be controlled for the installation/repairs of minor electrical work, ventilation components, telephone wires or computer cables, and sanding of walls for painting or wall covering to *only repair* small patches. It also includes plumbing that requires disruption to the water supply of more than one patient care area (e.g., > 2 rooms) for less than 30 minutes.
Type C	Any work that generates a moderate to high level of dust or requires demolition or removal of any fixed building components or assemblies (e.g., counter tops, cupboards, sinks). These include, but are not limited to, activities that require sanding of walls for painting or wall covering, removal of floor-coverings, ceiling tiles and casework, new wall construction, minor duct work or electrical work above ceilings, major cabling activities, and any activity that *cannot be completed* within a single work shift. It also includes plumbing that requires disruption to the water supply of more than one patient care area (e.g., > 2 rooms) for more than 30 minutes but less than 1 hour.
Type D	Major demolition, construction and renovation projects. These include, but are not limited to, activities that involve heavy demolition or removal of a complete cabling system and new construction that requires consecutive work shifts to complete. It also includes plumbing that results in disruption to the water supply of more than one patient care area (e.g., > 2 rooms) for more than 1 hour.

Part B: Population and Geographical Risks Groups

Group 1 Lowest Risk	Group 2 Medium Risk	Group 3 Medium to High Risk	Group 4 Highest Risk
• Office areas • Unoccupied wards	• All other patient care areas (e.g., cardiac rehab, ambulatory care clinics unless stated in Group 3 or 4) • Outpatient clinics (except for oncology & surgery) • Admission/discharge units	• Emergency room • Radiology/MRI • Post anesthesia care units • Labour and delivery (non OR) • Normal newborn nurseries • Day surgery • Nuclear medicine • Physiotherapy tank areas • Echocardiography • Pump team • Laboratories (specimens) • General med/surg. wards other than those listed in Group 4 • Pediatrics • Geriatrics • Long-term care	• All ICUs • All ORs • Oncology units and outpatient clinics for patients with cancer • Transplant units and outpatient clinics for patients who have received bone marrow or solid organ transplants • Wards and outpatient clinics for patients with AIDS or other immunodeficency • Dialysis units • Tertiary care nurseries • Labour & delivery operating rooms • All cardiac catherization & angiography areas • Cardiovascular/ cardiology patients • Anesthesia and pump areas • All endoscopy areas • Pharmacy admixture rooms • Sterile processing rooms

Part C: Construction Activity and Risk Group Matrix

A copy of the Risk Assessment and Preventive Measures Checklist must be sent to the Infection Prevention and Control Department when the matrix indicates that Class III and/or Class IV preventive measures are required (see shaded areas). Adaptations to the prevention measures can only be made after approval has been provided by the infection control personnel. Infection control personnel should also be consulted when construction activities need to be done on hallways adjacent to Class III and Class IV areas.

	Construction Activity			
Risk Group	**Type A**	**Type B**	**Type C**	**Type D**
Group 1	I	II	II	III / IV
Group 2	I	II	III	IV
Group 3	I	III	III / IV	IV
Group 4	III	III / IV	III / IV	IV

Part D: Recommendations for Infection Control Preventive Measures

Class I Date: Initials:	Engineer/Maintenance Staff & Contractors a) *Construction/Renovation Activities* Dust Control* • Immediately replace tiles displaced for visual inspection b) *Plumbing Activities* • Schedule water interruptions during low activity (e.g., evenings if at all possible) • Flush water lines prior to reuse • Observe for discoloured water • Ensure water temperature meets the standards set by the health care facility • Ensure gaskets and items made of materials that support the growth of *Legionella* are not being used • Ensure faucet aerators are not installed or used • Maintain as dry an environment as possible and report any water leaks that occur to walls and substructures	Environmental Services a) *Plumbing Activities* • Report discoloured water and water leaks to maintenance and ICP Medical/Nursing Staff a) *Construction/Renovation Activities* Risk Reduction • Minimize patients' exposure to construction/renovation area b) *Plumbing Activities* • Report discoloured water and water leaks to maintenance and ICP

*Note. Class II recommendations must be followed if dust should be created during the Type A construction activity.

Class II Date: Initials:	Engineer/Maintenance Staff & Contractors a) *Construction/Renovation Activities* 1) Dust Control • Execute work by methods to minimize dust generation from construction or renovation activities • Provide active means to minimize dust generation and migration into the atmosphere • use drop sheets to control dust • control dust by water misting work surfaces while cutting • seal windows and unused doors with duct tape • seal air vents in construction/renovation area • place dust mat at entrance to and exit from work areas 2) Ventilation • Disable the ventilation system in the construction/renovation area until the project is completed • Monitor need to change and/or clean filters in construction or renovation area 3) Debris Removal & Cleanup • Contain debris in covered containers or cover with a moistened sheet before transporting for disposal b) *Plumbing Activities* • Collection tanks and long pipes that allow water to stagnate should be avoided • Consider hyperchlorinating or superheating stagnant potable water (especially if *Legionella* is already present in hospital potable water supply)	Environmental Services a) *Construction/Renovation Activities* Dust Control • Wet mop and vacuum area with a HEPA filtered vacuum as needed and when work is completed • Wipe horizontal work surfaces with a disinfectant Medical/Nursing Staff a) *Construction/Renovation Activities* Risk Reduction • Identify high risk patients who may need to be temporarily moved away from the construction zone

Note. The above recommendations are to be considered in addition to those listed in Class I.

Class III	Engineer/Maintenance Staff & Contractors	Environmental Services
	a) *Construction/Renovation Activities* 1) Risk Reduction • Ensure ICP consultation has been completed and infection control measures have been approved 2) Dust Control • Erect an impermeable dust barrier from true ceiling (includes area above false ceilings) to the floor consisting of 2 layers of 6 ml polyethylene or Sheetrock • Ensure windows, doors, plumbing penetrations, electrical outlets and intake and exhaust vents are properly sealed with plastic and duct taped within the construction/renovation area	a) *Construction/Renovation Activities* • Increase frequency of cleaning in areas adjacent to the construction zone while the project is underway • In collaboration with infection control personnel ensure that construction zone is thoroughly cleaned when work is complete Infection Control Personnel a) *Construction/Renovation Activities* 1) Risk Reduction • Move high risk patients who are in or adjacent to the construction area • In collaboration with environmental services ensure that construction zone is thoroughly cleaned when work is complete • Inspect dust barriers 2) Traffic Control • In collaboration with the facility project manager designate a traffic pattern for construction workers that avoids patient care areas and a traffic pattern for clean or sterile supplies and equipment that avoids the construction area b) *Plumbing Activities* • Consider hyperchlorinating or superheating stagnant potable water (especially if *Legionella* is already present in hospital potable water supply) Medical/Nursing Staff a) *Construction/Renovation Activities* Risk Reduction • Move high risk patients who are in or adjacent to the construction area • Ensure that patients do not go near the construction area • In collaboration with environmental services and ICP ensure that construction zone is thoroughly cleaned when work is complete
Date:	• Air ducts and spaces above ceilings should be vacuumed if necessary • Construction workers should wear protective clothing that should be removed each time they leave the construction site before going into patient care areas • Do not remove dust barrier until the project is complete and the area has been cleaned thoroughly and inspected • Remove dust barrier carefully to minimize spreading dust and other debris particles associated with the construction project 3) Ventilation • Maintain negative pressure within construction zone by using portable HEPA equipped air filtration units • Ensure air is exhausted directly outside and away from intake vents or filtered through a HEPA filter before being recirculated • Ensure ventilation system is functioning properly and is cleaned if contaminated by soil or dust after construction or renovation project is complete 4) Debris Removal & Cleanup • Remove debris at the end of the work day • An external chute will need to be erected if the construction is not taking place on ground level • Vacuum work area with HEPA filtered vacuums daily or more frequently if	

	penetrations, electrical outlets and intake and exhaust vents are properly sealed with plastic and duct taped within the construction/renovation area	adjacent to the construction area • In collaboration with environmental services ensure that construction zone is thoroughly cleaned when work is complete
Initials:	• Air ducts and spaces above ceilings should be vacuumed if necessary • Construction workers should wear protective clothing that should be removed each time they leave the construction site before going into patient care areas • Do not remove dust barrier until the project is complete and the area has been cleaned thoroughly and inspected • Remove dust barrier carefully to minimize spreading dust and other debris particles associated with the construction project 3) Ventilation • Maintain negative pressure within construction zone by using portable HEPA equipped air filtration units • Ensure air is exhausted directly outside and away from intake vents or filtered through a HEPA filter before being recirculated • Ensure ventilation system is functioning properly and is cleaned if contaminated by soil or dust after construction or renovation project is complete 4) Debris Removal & Cleanup • Remove debris at the end of the work day • An external chute will need to be erected if the construction is not taking place on ground level • Vacuum work area with HEPA filtered vacuums daily or more frequently if	• Inspect dust barriers 2) Traffic Control • In collaboration with the facility project manager designate a traffic pattern for construction workers that avoids patient care areas and a traffic pattern for clean or sterile supplies and equipment that avoids the construction area b) *Plumbing Activities* • Consider hyperchlorinating or superheating stagnant potable water (especially if *Legionella* is already present in hospital potable water supply) Medical/Nursing Staff a) *Construction/Renovation Activities* Risk Reduction • Monitoring high risk patients who are in or adjacent to the construction area • Ensure that patients do not go near the construction area • In collaboration with environmental services and ICP ensure that construction zone is thoroughly cleaned when work is complete

Note. The above recommendations are in addition to those listed in

Class IV	Engineer/Maintenance Staff & Contractors	Environmental Services
Date: Initials:	a) *Construction/Renovation Activities* 1) Dust Control • Before starting the construction project erect an impermeable dust barrier that also has an anteroom • Place a walk-off mat outside the anteroom in patient care areas and inside the anteroom to trap dust from the workers shoes, equipment and debris that leaves the construction zone • Construction workers should leave the construction zone through the anteroom so they can be vacuumed with a HEPA filtered vacuum cleaner before leaving the work site; or they could wear cloth or paper coveralls that are removed each time they leave the work site • All personnel entering the construction zone are required to wear shoe covers • The construction workers must change the shoe covers each time they leave the work site • Holes in walls should be repaired within 8 hours or be temporarily sealed 2) Ventilation • Ensure negative pressure is maintained within the anteroom and construction zone • Ensure ventilation systems are working properly in adjacent areas • Review ventilation system requirements in the construction area with ICP to ensure system is appropriate and is functioning properly 3) Evaluation • Review infection control measures with other members of the planning team or delegate to evaluate their effectiveness and identify problems at the end of construction project b) *Plumbing Activities* • If there are concerns about *Legionella*, consider hyperchlorinating stagnant potable water or superheating and flushing all distal sites before restoring or repressurizing the water system	a) *Construction/Renovation Activities* Evaluation • Review infection control measures with other members of the planning team or delegate to evaluate their effectiveness and identify problems at the end of construction project Infection Control Personnel a) *Construction/Renovation Activities* 1) Risk Reduction • Regularly visit the construction site to ensure preventive measures are being followed 2) Evaluation • Review infection control measures with other members of the planning team or delegate to evaluate their effectiveness and identify problems at the end of construction project b) *Plumbing Activities* • If there are concerns about *Legionella*, consider hyperchlorinating stagnant potable water or superheating and flushing all distal sites before restoring or repressurizing the water system Medical/Nursing Staff a) *Construction/Renovation Activities* Evaluation • Review infection control measures with other members of the planning team or delegate to evaluate their effectiveness and identify problems at the end of construction project b) *Plumbing Activities* • Consider using another source of potable water for patients who are at greatest risk until hospital potable water has been cleared for signs of *Legionella* after major plumbing installation/repairs

Note. The above recommendations are to be considered in addition to those listed in Class I, II and III.

Adapted from *Reducing dust and danger during construction*. Hospital Infection Control 1997;24:26-29. (with oral permission from Virigina Kennedy, original creator of the tool, formerly from St. Luke's Episcopal Hospital, Houston, TX).

Appendix B: Published Standards/Codes Related to Construction

The following list is not exhaustive. It should be noted that each province or territory may incorporate the National Building Codes in a slightly different manner since these codes represent the minimum requirements. As well, each municipality or region may incorporate the provincial or territorial building codes in a slightly different manner for the same reason.

National Resources

- *Canadian Construction Documents Committee (CCDC)

- Canadian Standards Association

  1) Canadian Standards Association. *Special requirements for plumbing installations in health care facilities (CAN/CSA-Z317.1-98).* Toronto: Canadian Standards Association, 1998.

  2) Canadian Standards Association. *Special requirements for heating, ventilation, and air conditioning (HVAC) systems in health care facilities (CAN/CSA-Z317.2-M91).* Toronto: Canadian Standards Association, 1991.

  3) Canadian Standards Association. *Handling of waste materials within health care facilities (CAN/CSA-Z317.10-88).* Toronto: Canadian Standards Association, 1988.

- *Canadian Contractors Association

- Health and Welfare Canada. *Interior finishes in hospital design*. 1st ed. Ottawa: Ministry of Supply and Services Canada, 1988.

- Health Canada. *Laboratory biosafety guidelines.* 2nd ed. Ottawa, ON: Supply and Services Canada, Catalogue Number MR21-1/1996E, 1996.

- National Building Code of Canada (NCR-BLDG CODE) (copies can be obtained from CSA on behalf of the National Research Council)

- National Plumbing Code of Canada (NCR-PLUMB CODE) (copies can be obtained from CSA on behalf of the National Research Council)

- *National Fire Protection Association Standards

Provincial Resources

Readers are advised to check their province or territory for the following:

- *Provincial Building Code

- *Provincial Fire Code

- *Provincial Hydro Electrical Safety Code

- *Provincial Bid Depository Council
- *Provincial Association of Architects
- *Provincial Engineers Association
- *Provincial General Contractors Association
- *Public Health Act
- *Ministry of Health Act
- *Public Hospitals Act
- *Homes for the Aged and Rest Homes Act
- *Charitable Institutions Act
- *Nursing Homes Act
- *Elderly Persons Centres Act
- *Tobacco Control Act
- *Environmental Protection Act
- *Occupational Health and Safety Act
- *Construction Lien Act

In addition, some provinces and territories have developed a manual that provides information on the capital planning process. Health care facilities must follow this process when they embark on construction or renovation projects to ensure that 1) resources are used efficiently and effectively; 2) the approval process is streamlined; and 3) the key participants' roles and responsibilities are identified[94]. A list of the available manuals is provided below. At present, there are no manuals available for the North West Territories, British Columbia, Quebec, Prince Edward Island, or Newfoundland and Labrador. The reader is advised to contact the provincial Ministry of Health to obtain further information on the manuals or for specific information on the process that should be followed if no manual is available.

Saskatchewan: Saskatchewan Health. *Planning guide for Saskatchewan health districts part III: facilities planning.* Regina, SK: Capital and Special Operating Policy Unit, Saskatchewan Health (currently being revised).

Ontario: Ontario Ministry of Health. *Capital planning manual: a guide to the capital planning process.* Toronto, ON: Queen's Printer for Ontario, 1996.

Nova Scotia: Nova Scotia Department of Health. *Health care capital construction guidelines*. Halifax, NS: Nova Scotia Department of Health, 1998

Yukon: Yukon Government Services. *Building development projects procedures manual.* Whitehorse, YK: Yukon Health and Social Services, 1992.

Municipal/Regional Resources

- *Local Construction Association
- *Local planning and zoning by-laws

Other Resources

- Guidelines/Practice Parameters Committee of the American College of Critical Care Medicine, Society of Critical Care Medicine. *Guidelines for intensive care unit design*. Crit Care Med 1995;23:582-88.
- American Institute of Architects Academy of Architecture for Health. *Guidelines for design and construction of hospital and health care facilities*. Washington: American Institute of Architects Press, 1997.
- *American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) handbooks
- Lavoie J, Lazure L. *Guide for the prevention of microbial growth in ventilation systems.* Montreal, Quebec: Institut de recherche en santé et en sécurité du travail du Québec.
- Lelièvre M., Ouellette JM., Thibault B et al. Hôpital général de courte durée: programme type détaillé. Quebec: Ministère de la Santa et des Services sociaux, 1997.
- Van Vliet J, Drerup O, Feigin J et al. *Building materials for the environmentally hypersensitive*. Ottawa: Canada Mortgage and Housing Corporation, 1995.

Note. *Represents resources that were listed in Ontario Ministry of Health. *Capital planning manual: a guide to the capital planning process.* Toronto, ON: Queen's Printer for Ontario, 1996.